Claims:

1. A process for the preparation of zeaxanthin wherein said process comprises culturing a recombinant cell containing farnesyl pyrophosphate and isopentyl pyrophosphate under culture conditions sufficient for the expression of enzymes which catalyze the conversion of the farnesyl pyrophosphate and isopentyl pyrophosphate to zeaxanthin, said recombinant cell being a host cell transformed by an expression vector comprising a regulatory sequence and a polynucleotide containing the following DNA sequences which encode said enzymes:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE) or a DNA sequence which is substantially homologous,

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB) or a DNA sequence which is substantially homologous,

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI) or a DNA sequence which is substantially homologous,

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY) or a DNA sequence which is substantially homologous,

e) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$) or a DNA sequence which is substantially homologous;

and isolating the zeaxanthin from such cells or the culture medium.

2. The process of claim 1 wherein said DNA sequences are:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE),

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB),

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI),

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY), and

e) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$).

3. The process of claim 2 wherein:

a) the GGPP synthase has the amino acid sequence of Figure 8,

b) the prephytoene synthase has the amino acid sequence of Figure 9,

c) the phytoene desaturase has the amino acid sequence of Figure 10,

d) the lycopene cyclase has the amino acid sequence of Figure 11, and

e) the β-carotene hydroxylase has the amino acid sequence of Figure 34.

4. The process of claim 3 wherein:

a) the DNA sequence encoding the GGPP synthase comprises bases 2521-3408 of Figure 7,

b) the DNA sequence encoding the prephytoene synthase comprises bases 4316-3405 of Figure 7,

c) the DNA sequence encoding the phytoene desaturase comprises bases 4313-5797 of Figure 7,

d) the DNA sequence encoding the lycopene cyclase comprises bases 5794-6942 of Figure 7, and

e) the DNA sequence encoding the β-carotene hydroxylase comprises the sequence of Figure 33.

5. A process for the preparation of canthaxanthin wherein said process comprises culturing a recombinant cell containing farnesyl pyrophosphate and isopentyl pyrophosphate under culture conditions sufficient for the expression of enzymes which catalyze the conversion of the farnesyl pyrophosphate and isopentyl pyrophosphate to canthaxanthin, said recombinant cell being a host cell transformed by an expression vector comprising a regulatory sequence and a

polynucleotide containing the following DNA sequences which encode said enzymes:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE) or a DNA sequence which is substantially homologous,

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB) or a DNA sequence which is substantially homologous,

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI) or a DNA sequence which is substantially homologous,

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY) or a DNA sequence which is substantially homologous, and

e) a DNA sequence which encodes the ß-carotene ß4-oxygenase of microorganism E-396 ($crtW_{E396}$) or a DNA sequence which is substantially homologous;

and isolating the canthaxanthin from such cells or the culture medium.

6. The process of claim 5 wherein said DNA sequences are:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE),

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB),

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI),

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY), and

e) a DNA sequence which encodes the ß-carotene ß4-oxygenase of microorganism E-396 ($crtW_{E396}$).

7. The process of claim 6 wherein:

a) the GGPP synthase has the amino acid sequence of Figure 8,

b) the prephytoene synthase has the amino acid sequence of Figure 9,

c) the phytoene desaturase has the amino acid sequence of Figure 10,

d) the lycopene cyclase has the amino acid sequence of Figure 11, and

e) the ß-carotene ß4-oxygenase has the amino acid sequence of Figure 32.

8. The process of claim 7 wherein:

a) the DNA sequence encoding the GGPP synthase comprises bases 2521-3408 of Figure 7,

b) the DNA sequence encoding the prephytoene synthase comprises bases 4316-3405 of Figure 7,

c) the DNA sequence encoding the phytoene desaturase comprises bases 4313-5797 of Figure 7,

d) the DNA sequence encoding the lycopene cyclase comprises bases 5794-6942 of Figure 7, and

e) the DNA sequence encoding the ß-carotene ß4-oxygenase comprises the sequence of Figure 31.

9. A process for the preparation of astaxanthin and adonixanthin wherein said process comprises culturing a recombinant cell containing farnesyl pyrophosphate and isopentyl pyrophosphate under culture conditions sufficient for the expression of enzymes which catalyze the conversion of the farnesyl pyrophosphate and isopentyl pyrophosphate to astaxanthin and adonixanthin, said recombinant cell being a host cell transformed by an expression vector comprising a regulatory sequence and a polynucleotide containing the following DNA sequences which encode said enzymes:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE) or a DNA sequence which is substantially homologous,

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB) or a DNA sequence which is substantially

homologous,

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI) or a DNA sequence which is substantially homologous,

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY) or a DNA sequence which is substantially homologous,

e) a DNA sequence which encodes the ß-carotene ß4-oxygenase of Alcaligenes PC-1 (crtW) or a DNA sequence which is substantially homologous, and

f) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$) or a DNA sequence which is substantially homologous;

and isolating the astaxanthin and adonixanthin from such cells or the culture medium.

10. The process of claim 9 wherein said DNA sequences are:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE),

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB),

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI),

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY),

e) a DNA sequence which encodes the ß-carotene ß4-oxygenase of Alcaligenes PC-1 (crtW), and

f) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$).

11. The process of claim 10 wherein:

a) the GGPP synthase has the amino acid sequence of Figure 8,

b) the prephytoene synthase has the amino acid sequence of Figure 9,

c) the phytoene desaturase has the amino acid sequence of Figure 10,

d) the lycopene cyclase has the amino acid sequence of Figure 11,

e) the ß-carotene ß4-oxygenase has the amino acid sequence of Figure 25, and

f) the β-carotene hydroxylase has the amino acid sequence of Figure 34.

12. The process of claim 11 wherein:

a) the DNA sequence encoding the GGPP synthase comprises bases 2521-3408 of Figure 7,

b) the DNA sequence encoding the prephytoene synthase comprises bases 4316-3405 of Figure 7,

c) the DNA sequence encoding the phytoene desaturase comprises bases 4313-5797 of Figure 7,

d) the DNA sequence encoding the lycopene cyclase comprises bases 5794-6942 of Figure 7,

e) the DNA sequence encoding the ß-carotene ß4-oxygenase comprises the sequence of Figure 25, and

f) the DNA sequence encoding the β-carotene hydroxylase comprises the sequence of Figure 33.

13. A process for the preparation of astaxanthin and adonixanthin wherein said process comprises culturing a recombinant cell containing farnesyl pyrophosphate and isopentyl pyrophosphate under culture conditions sufficient for the expression enzymes which catalyze the conversion of the farnesyl pyrophosphate and isopentyl pyrophosphate to astaxanthin and adonixanthin, said recombinant cell being a host cell transformed by an expression vector comprising a regulatory sequence and a polynucleotide containing the following DNA sequences which encode said enzymes:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE) or a DNA sequence which is substantially homologous,

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB) or a DNA sequence which is substantially homologous,

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI) or a DNA sequence which is substantially homologous,

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY) or a DNA sequence which is substantially homologous,

e) a DNA sequence which encodes the b-carotene b4-oxygenase of microorganism E-396 ($crtW_{E396}$) or a DNA sequence which is substantially homologous, and

f) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$) or a DNA sequence which is substantially homologous;

and isolating the astaxanthin and adonixanthin from such cells or the culture medium.

14. The process of claim 13 wherein said DNA sequences are:

a) a DNA sequence which encodes the GGPP synthase of Flavobacterium sp. R1534 (crtE),

b) a DNA sequence which encodes the prephytoene synthase of Flavobacterium sp. R1534 (crtB),

c) a DNA sequence which encodes the phytoene desaturase of Flavobacterium sp. R1534 (crtI),

d) a DNA sequence which encodes the lycopene cyclase of Flavobacterium sp. R1534 (crtY),

e) a DNA sequence which encodes the ß-carotene ß4-oxygenase of microorganism E-396 ($crtW_{E396}$), and

f) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$).

15. The process of claim 14 wherein:

a) the GGPP synthase has the amino acid sequence of Figure 8,

b) the prephytoene synthase has the amino acid sequence of Figure 9,

c) the phytoene desaturase has the amino acid sequence of Figure 10,

d) the lycopene cyclase has the amino acid sequence of Figure 11,

e) the ß-carotene ß4-oxygenase has the amino acid sequence of Figure 32, and

f) the β-carotene hydroxylase has the amino acid sequence of Figure 34.

16. The process of claim 15 wherein:

a) the DNA sequence encoding the GGPP synthase comprises bases 2521-3408 of Figure 7,

b) the DNA sequence encoding the prephytoene synthase comprises bases 4316-3405 of Figure 7,

c) the DNA sequence encoding the phytoene desaturase comprises bases 4313-5797 of Figure 7,

d) the DNA sequence encoding the lycopene cyclase comprises bases 5794-6942 of Figure 7,

e) the DNA sequence encoding the ß-carotene ß4-oxygenase comprises the sequence of Figure 31, and

f) the DNA sequence encoding the β-carotene hydroxylase comprises the sequence of Figure 33.

17. A process for the preparation of adonixanthin wherein said process comprises culturing a recombinant cell containing farnesyl pyrophosphate and

isopentyl pyrophosphate under culture conditions sufficient for the expression of enzymes which catalyze the conversion of the farnesyl pyrophosphate and isopentyl pyrophosphate to adonixanthin, said recombinant cell being a host cell transformed by an expression vector comprising a regulatory sequence and a polynucleotide containing the following DNA sequences which encode said enzymes:

a) a DNA sequence which encodes the GGPP synthase of microorganism E-396 ($crtE_{E396}$) or a DNA sequence which is substantially homologous,

b) a DNA sequence which encodes the prephytoene synthase of microorganism E-396 ($crtB_{E396}$) or a DNA sequence which is substantially homologous,

c) a DNA sequence which encodes the phytoene desaturase of microorganism E-396 ($crtI_{E396}$) or a DNA sequence which is substantially homologous,

d) a DNA sequence which encodes the lycopene cyclase of microorganism E-396 ($crtY_{E396}$) or a DNA sequence which is substantially homologous,

e) a DNA sequence which encodes the b-carotene b4-oxygenase of microorganism E-396 ($crtW_{E396}$) or a DNA sequence which is substantially homologous, and

f) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$) or a DNA sequence which is substantially homologous,

said host cell being substantially free of other polynucleotides of microorganism E-396;

and isolating the adonixanthin from such cells or the culture medium.

18. The process of claim 17 wherein said DNA sequences are:

a) a DNA sequence which encodes the GGPP synthase of microorganism E-396 ($crtE_{E396}$),

b) a DNA sequence which encodes the prephytoene synthase of microorganism E-396 ($crtB_{E396}$),

c) a DNA sequence which encodes the phytoene desaturase of microorganism E-396 ($crtI_{E396}$),

d) a DNA sequence which encodes the lycopene cyclase of microorganism E-396 ($crtY_{E396}$),

e) a DNA sequence which encodes the ß-carotene ß4-oxygenase of microorganism E-396 ($crtW_{E396}$), and

f) a DNA sequence which encodes the β-carotene hydroxylase of microorganism E-396 ($crtZ_{E396}$).

19. The process of claim 18 wherein the polynucleotide is plasmid pE396CARcrtW-E.

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